4th Quarterly Report (April – June 2000)

MWTS Testing—E.N.R. Test Cell Baseline Calibration & Phase 2 Activities at Cypress Wetland

Prepared for

South Florida
Water Management District

April 2001

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Contents

1.0 Executive Summary for Fourth Quarter of Operational Testing

1.1 Summary of Results

This report provides the status and results for the fourth quarter of operational testing at the ENR for the MWTS project, as of June 30, 2000. With the close of the third quarter the baseline calibration period was completed and the fourth quarter was the first full quarter of experimental operation. Water quality sampling for field and laboratory parameters has followed the schedule defined in the MWTS research plan and work plan.

This section is a synopsis of results more quantitatively described in subsequent sections. The reader is encouraged to refer to the subsequent sections for specific numeric details of the trends summarized here.

The subsequent sections of the report address the following:

Section 2—Background and Purpose
Section 3—Meteorological Data for ENR
Section 4—ENR Water Quality Sampling
Section 5—Phase 2--Treatment Pond Design
Section 6—Marsh Readiness and Ionic Conditioning

1.1.1 Everglades Nutrient Removal Test Cell Experimental Results

Introduction

Testing of chemical treatment followed by marsh conditioning was initiated at the Everglades Nutrient Removal Project (ENR) in three cells of the North Test Cell (NTC) site and at two cells in the South Test Cell site.

- North Test Cells
  - NTC 2 — iron (Fe) treatment cell
  - NTC 3 — control cell
  - NTC 4 — aluminum (Al) treatment
- South Test Cells
  - STC 5 — alternate control cell
  - STC 6 — designated control cell
  - STC 7 — aluminum (Fe) treatment cell

Hydrologic Regime

The target operating depth for the Test Cells is 0.33 m and the target hydraulic loading rate (HLR) is 10 centimeters per day. For the quarter water depth in the test cells has ranged from 0. 3 to 0.4 m. HLRs were in the range of 6.8 to 7.5 cm / d.

Water Balance

A water balance for each test cell was calculated from the measured and estimated inflows, and changes in storage volume. Because the test cells are lined seepage loss is assumed to be zero. Outflow has been calculated by difference due to the uncertainty in estimating outflow from the weir settings. At the conclusion of the baseline period (Q1 and Q2) a water balance for each test cell was developed (see 2nd Quarterly Report). In that analysis inflow and outflow balanced for only one of the six test cells, NTC 3. The high positive and negative residuals for the other five test cells indicated variation in one or more outflows and storage in response to a variety of factors. Over the course of the baseline period, water balance residuals were expected to become relatively small. The project team implemented a quality control plan for field data collection. Some of the steps include the following: 1) less frequent adjustment of weir height in water level 2) careful measurement of weir height setting, and 3) verify that our measurement of flow over the weirs is accurate. In addition we assessed the value of calculating the water balance on a daily basis rather than on a monthly average. The water balance calculations for Q1 and Q2 indicated that the magnitude of the residuals remained high.

Water Quality

This section provides a very brief synopsis of treatment effects at the ENR test cells for the fourth quarter; in-depth discussion is provided in Section 4 of the report.

All chemical treatments pilot units (two in the NTC and one in the STC) operated through the entire fourth quarter. Results of comparisons of constituent concentration in the raw inflow with test cell outflow, from the northern and southern ENR sites are as follows:

- Fe and Al treatments reduced TDP, SRP, TDP, DOP, TN, TKN, org-N, and TOC concentrations relative to the control. Color was reduced in both Al treatments.
- It appears that the wetland contributed TDP over the period of pilot plant operation (control cell results) but overall the treatment cells demonstrated net removal (NTC 2 and NTC 4), or little net change (STC 7).
- Due to episodic floc overflow TP and TPP concentrations in pilot plant effluent (inflow to wetland) were not consistently lower than the control cell influent; however, TP and TPP concentrations in treatment wetland outflows were generally lower than the control cell outflows.
- TPP in the pilot unit effluent was quickly removed at the head of the wetland.

STC treatment cell TP removal rate (20%) was similar to the south control cell TP removal rate (18%).

Phosphorus

In the fourth quarter control cell NTC3 raw water inflow TP concentration was greater than that from the wetland outflow. This trend was often reversed for the control cells STC5 and STC6. For both locations inflow TP was relatively evenly split between particulate and dissolved fractions.

Raw water influent [TP] was in a range of 115 to 230 ppb at the NTCs and 30 to 180 ppb at the STCs. This represents an increase over past quarters for both sites. NTC treatment wetland outflow TP concentrations were lower for the treatments compared to the control. Iron treatment resulted in a 50-70% reduction and aluminum a 50-85% reduction. The [TP] and [TPP] concentrations decrease from from inflow to outflow. This result indicates that particulate P from the respective chemical treatment effluent was removed at the head of the wetland. The treatment effect on wetland outflow is evident in the time series and quarterly boxplots.

At the southern ENR location outflow [TP] was 10% to 20% lower for the aluminum treatment versus control cell STC6.

Phosphorus Species

Chemical analyses provide a breakdown of TP into total particulate P (TPP), total dissolved P (TDP), dissolved organic P (DOP) and soluble reactive P (SRP). A summary of TPP, TDP and SRP is as follows:

- TPP—raw water influent TPP levels at NTCs were typically greater than or equal to levels at STCs. Water quality gradient data (Appendix C) show treatment effect on wetland outflow [TPP] for the fourth quarter. Outflow TP concentration was higher for the control (NTC3) relative to the chemical treatments (NTC2 and NTC4). As noted above, for the treatment period, [TPP] drop quickly in the wetland for both chemical treatment cells at the north site. For the quarter the northern treatment cells had inflow [TPP] in the range of 60 to 80 ppb. Monthly average outflow TPP concentration was 20 to 39 ppb for the iron treatment and the control, but was averaged 12 ppb for the aluminum treatment. For the STCs, inflow [TPP] averaged 30ppb. The outflow concentration for control cells were equal to or higher than the inflow; in contrast, the outflow concentration for the aluminum treatment averaged 20 ppb.

- TDP—NTC control cell (NTC 3) and treatments had lower outflow TDP concentrations as compared to inflow values. The average outflow [TDP] for the two treatments (Fe and Al) were, however, lower than the control, approximately 20 ppb as compared to 50 ppb. For the STCs the wetland influent [TDP] ranged from 20 to 80 ppb, and the wetland effluent ranged from 10 to 40 ppb. For the STCs there was no clear chemical treatment effect comparing inflow versus outflow [TDP]. The effect of treatment is apparent at the north site with significant reductions in [TDP] compared to the control.

- SRP—Influent [SRP] rose steadily at the northern site for the quarter from approximately 18 ppb at the start to 115 ppb at the close. Influent [SRP] was higher at NTCs compared to STCs (averages of 45 ppb versus 11 ppb). At the southern site outflow [SRP] is typically less than 10 ppb for all three test cells. The aluminum treatments and the control at the north site were effective at reducing average SRP concentrations to less than 10 ppb.

Nitrogen

For the fourth quarter the raw water inflow [TN] was approximately equal at both sites (2.43 mg/l for NTC and 2.23 mg/L for STC). Time series (Appendix B) display patterns of inflow [TN] that are remarkably similar among the three test cells at each location. At both locations the inflow and outflow TN values are approximately equal for the control cells (NTC3, STC6). NTC and STC results show a treatment effect with lower wetland effluent [TN] for the treatments as compared to the controls.

Other Water Quality Parameters

For several of the remaining parameters the inflow and outflow concentrations are approximately equal at the respective test cells. Included in this group are TDS, TSS, calcium, magnesium, and aluminum. Other observations for Q4 are as follows.

- Color—chemical treatments at both the northern and southern sites reduced color relative to the control. At the north site, the Al treatment resulted in lower color values than the Fe treatment. The control treatments at both sites had no apparent effect on color.
- TOC—results for the fourth quarter are similar to those for color, the chemical treatments at both locations resulted in lower outflow [TOC], compared to the controls. At the north site Al treatment resulted in lower TOC values relative to the iron treatment.
- Dissolved silica—results follow the pattern noted for color and TOC, reduced concentration for outflow as compared to inflow for Al and Fe treatments.
- The ferric chloride treatment (NTC 2) resulted in higher outflow concentrations of iron and chloride than the either the control or the aluminum treatment. At the remaining test cells the inflow and outflow values are approximately equal for iron and chloride.
- Hardness & alkalinity-for both parameters there are no apparent treatment effects at either the north or south site; outflow concentrations for controls and treatments are similar.

Mass Balance

Phosphorus

The net phosphorus removal; trend continued in Q4. Iron, control and aluminum treatments removed 67%, 50% and 79% of influent P load, respectively. T the northern site the monthly average removal rate increased over the quarter for both chemical treatments and the control . For the STCs where the trend for Q3 was net export of P, removal averaged18% in the control cell and 20% in the Al treatment cell.

Phosphorus Species

A summary of each P-species follows:

- **TPP**—patterns of removals for TPP are similar to those of TP at both locations. The NTCs show regular pattern of net removals on monthly and cumulative basis. The average TPP removal rate for the quarter was approximately equal for the control and iron treatments at 60%, while the aluminum treatment yielded a an average of 85%. The STCs exhibited month to month variation between positive and negative monthly TPP removal rates but the Al treatment cell had net removal for the quarter of 35% of the TP load due primarily to high loading and effective removal in April.

- **TDP**—All NTC cells showed net TDP removal for the quarter, with the treatment cells much higher than the control cell percent removal. Net removal rates for the iron and aluminum treatment cells averaged 73% versus 42% for the control. The STC control and treatment cell removal rates were negative for April and May, positive for June, and positive overall. The control cell retained a higher fraction the TDP than did the treatment cell.

- **SRP**—The northern test cells sowed net removal for SRP over the quarter with removal rates of 50%, 80%, and 90% for iron, control, and aluminum treatments, respectively. For the STCs both the control (STC6) and aluminum treatments had removal rates in range of 50% to 60%.

- **DOP**—DOP removal rates are variable at all locations except for the NTC Al treatment (NTC-4), which displayed a consistent removal of DOP. Overall quarterly mass balance (% removal) was similar for the NTC iron .and Al treatments.

Nitrogen

A chemical treatment effect is apparent at the NTCs for the fourth quarter. TN removal averaged 40% for the iron treatment, 47% for the aluminum treatment, and 17% for the control cell. At the south site, the quarterly mean percent mass removal rates for the control and aluminum treatments were both positive and very similar in magnitude to their counterparts in the NTC.

1.1.2 Chemical Treatment Pilot Plant Operation

Three chemical treatment units (two in the north cells and one in the south) were operated for the entire quarter. Target flow rate to the plant was 37 gallons per minute (gpm) for the quarter. The target flow of 37 gpm yields a hydraulic loading rate of 4 in / d (10 cm / d) to the wetland cells (incremental rate of 1 ft / d at the 1 / 3 sampling point in the cells).

Some adjustments to dosing have been required, due to higher TP concentration during startup as compared to waters used in jar tests used for setting dosages. Most operational changes were implemented during the first week in May, when an intensive evaluation of operating conditions at the North site chemical units was conducted. (see North Test Pilot Unit Evaluation memo in Appendix D) The operational parameters that were evaluated and adjusted during the first week in May were as follows:

1. Chemical addition points were adjusted to maximize dispersion of the chemicals. The PACL addition point was moved from the first rapid mix chamber to the splitter box. The ferric chloride addition point was changed to disperse at approximately one inch from the impeller of the first rapid mix chamber, while the sodium hydroxide was injected into the raw water line up-stream of the chamber. The polymer addition point was moved to disperse at approximately one inch above the impeller of the second rapid mix chamber. While improvement to solids formation and settling was not evident, it is reasonable to believe that dispersion of chemicals was been enhanced.

2. Mixer / Flocculator Modifications. A larger impeller was evaluated in the polymer mixing chamber with the result of excessive vibration to the motor and excessive turbulence which effected the flocculation basin. The flocculation basin flocculator speed was reduced in the basins with marginal improvement on floc formation. The flocculator

for the PACl pilot unit was reversed in rotational direction to mirror the direction of the ferric chloride unit. The rotation change was made to counter the direction of flow from the polymer chamber, thereby reducing the chance of short-circuiting. The combination mixing direction change and reduction of flocculator speed appeared to slightly improve floc formation.

3. Coagulant Dosage. The calibration procedure and feed rates of all chemicals were checked and verified as correct. Increasing the coagulant dose in combination with the polymer improved the floc characteristics slightly. On May 4, Fe coagulant dose was increased from the previous target rate of 28 mg/L as Fe to 42 mg/L as Fe. On May 6, aluminum coagulant dose was increased at both the north and south plants from the previous target of 13.5 mg/L to 27 mg/L as Al.

4. Polymer Type. Two additional polymers were evaluated by addition to the North pilot units. A high charge and high molecular emulsion (Cytec AF-126) was evaluated first on the PACl pilot unit. This product's effect was relatively fast and apparent with significant improvement in discrete floc formation and larger floc size. A significant reduction in solids carry-over from the settler was not apparent. The high molecular weight, high charge, dry polymer used successfully by the CT/SS team (Cytec A-130) was applied to both North site pilot units. There was a significant enough improvement in floc particle formation that it was selected for a longer term evaluation at both sites and all pilot units. However, reductions of solids carry-over from the plate settlers were only marginal with the units in recirculation mode.

Few operational adjustments have been made since the early May adjustment period. The target coagulant dosage was further increased in all units on June 11 to try to increase TDP removal. The new target rates that have been held since that time are approximately 35 mg/L Al at the North (NTC-4)and South (STC-7) aluminum plants, and 56 mg/L Fe at the North (NTC-2)iron plant.

1.1.3 Design of Chemical Treatment Pond

The design of the chemical treatment pond for the Phase 2 testing at the Seminole Reservation was completed in the third quarter. Final modifications to the design were completed after a vendor was selected. Phase I of the project was bid, and the electric feed, influent pump at the west feeder canal, and pipeline were installed in July. The rehydration of the cypress marsh began in the final week of July. The Phase II bid package is ready for bidding project staff have been exploring opportunities to maximize Tribe involvement in the construction of these sites.

1.1.4 Evaluation of Marsh Readiness

Marsh readiness refers to the ensemble water quality characteristics of the water leaving the treatment wetland and the similarity of that water to appropriate receiving waters. The concern is whether chemically treated waters are “marsh ready,” that is of acceptable quality to be discharged to the marshes of the Everglades ecosystem.

The marsh readiness of water from the test cells was evaluated using a set of ionic parameters presented using Stiff diagrams, Schoeller Plots, and Radial Plots. Pre-treatment period parameter value averages were compared to treatment period parameter values for the NTCs and STCs and Water Conservation Areas.

Pretreatment and treatment period Stiff diagrams for the cells were very similar. Increased iron and chloride levels from the treatment period Fe cell was the only clear difference. Both pre treatment and treatment period Stiff diagrams were very similar to that of the WCA-2A site, and least similar to the Stiff diagram of an interior site in the Loxahatchee Refuge. This is expected since the main source water for the ENR test cells is the same as that for WCA 2A.

1.2 General Conclusions

General conditions follow.

- Water Regime—The hydrologic targets (depth and hydraulic loading rates) for the wetland cells were met throughout the quarter. (Section 4.2)
- Water Balance—Water balances close if outflows are calculated by difference. (Section 4.2)
- Water Quality—Concentrations of phosphorus and nitrogen decreased across the NTC systems, with experimental treatment system decreases far exceeding the control cell decreases. In the STCs no clear pattern was apparent. (Section 4.4)
- Mass Balance—TP mass balances clearly showed the effect of chemical treatments in the NTCs, and the treatments clearly had different effects, with aluminum treatment showing the greatest removal rates. (Section 4.5)
- Treatment Pond Design-Design was finished in the third quarter. Pond construction and wetland hydration began in July 2000. (Section 5.0)
- Marsh Readiness – Stiff, Schoeller, and Radial Plots were used to compare ionic constituent data sets from the pre-treatment period to treatment period data, and both data sets to interior sites in the Water Conservation Areas. Experimental and control data diagrams were very similar to WCA-2A interior site diagrams. (Section 6.0)

2.0 Purpose

The South Florida Water Management District (District) is conducting research focused on potential advanced treatment technologies to support reduction of phosphorus loads in surface waters entering the remaining Everglades. Particular focus is being placed on the treatment of excess surface waters from the Everglades Agricultural Area (EAA) as well as Lake Okeechobee water that is diverted through the primary canal system to the Lower East Coast of Florida.

Federal- and State-level Everglades restoration efforts are focused on addressing two programmatic factors: reduction of stormwater-based phosphorus (P) loading to the Water Conservation Areas (WCAs)/Everglades National Park, and promotion of sheet flow through the system. The Everglades Forever Act (EFA) mandates an interim performance standard of producing treated waters with total phosphorus (TP) concentrations of 50 parts per billion (ppb) or less. However, this may not be low enough to prevent alteration of the aquatic and wetland ecosystems downstream in the remaining Everglades; ongoing research and an anticipated, formal rulemaking process will seek to define what will be the ultimate TP standard.

The Managed Wetlands Treatment System (MWTS) evaluation was authorized in November 1998. The objective of this research (Phase I) is to identify preferred technologies that should be designed and implemented full-scale to optimize treatment performance of the cattail-based Stormwater Treatment Areas (STA) during Phase II of the State's Everglades Construction Program (ECP).

Sampling at the ENR Test Cells began in the first week of July 1999 under the baseline sampling period. The baseline calibration period ran through to the beginning of February 2000. During the calibration period, untreated source water was being discharged to both the North and South Test Cells.

Chemical treatment of source water with either ferric chloride or an aluminum chloride compound was instituted during the third quarter in three cells, two treatments in the north test cell site and one treatment in the south test cell site. An additional cell in each location serves as a control. The chemical treatment period is scheduled to run for 12 months, through to February 28, 2001.

It should be noted that the information contained in this document remains preliminary and draft. Complete quality control (QC) review of all data sets has not been conducted on all of the information being transmitted because some of it was only recently received from the various analytical support laboratories and some data sets for this quarter have yet to be completely reported by those laboratories. This document is an interim report prepared under Task 2 of the MWTS study program contract held by CH2M HILL. It provides a brief summary of progress as it relates to data collection, on the MWTS Research Project during the fourth quarter (April - June 2000).

Exhibit 2-1 provides a plan view of a typical MWTS Test Cell showing sampling locations and walkways.

3.0 Meteorological Data

3.1 Solar Radiation

Solar radiation is being continuously monitored by CH2M HILL at the South ENR STRC using a pyranometer and phostosynthetically active radiation (PAR) quantum sensor. Exhibits 3-1 and 3-2 illustrate total solar radiation and PAR, respectively, at this site for the first four quarters. PAR and total insolation monitored during this quarter averaged 38.46 Einstein per square meter per day ($E/m^2/d$) and 23.29 megajoules per square meter per day $MJ/m^2/d$, respectively. Average total insolation and PAR both exhibited an increase from last quarter.

EXHIBIT 3-1
Total Solar Radiation Measured at the South ENR STRC

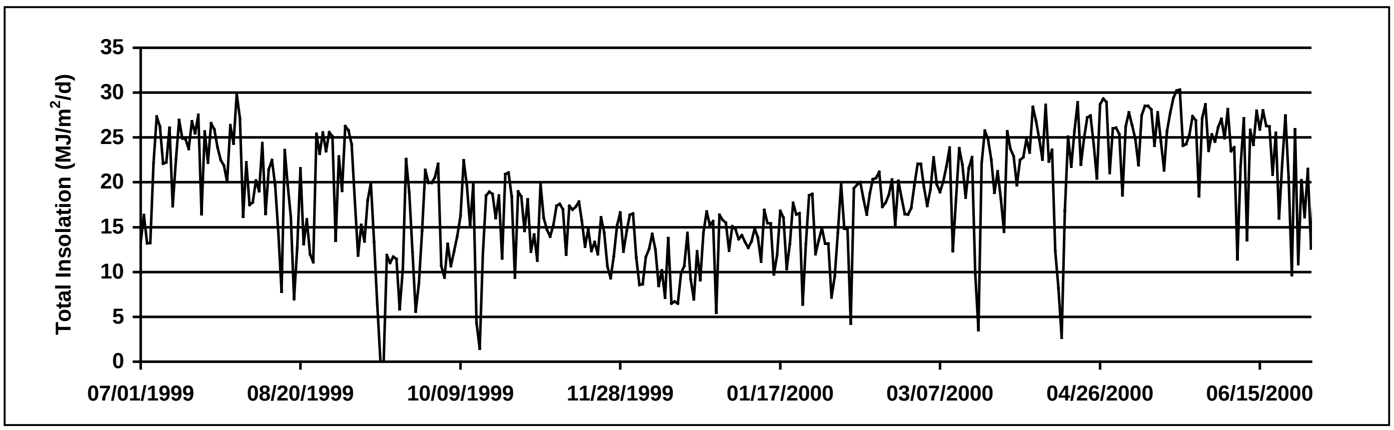
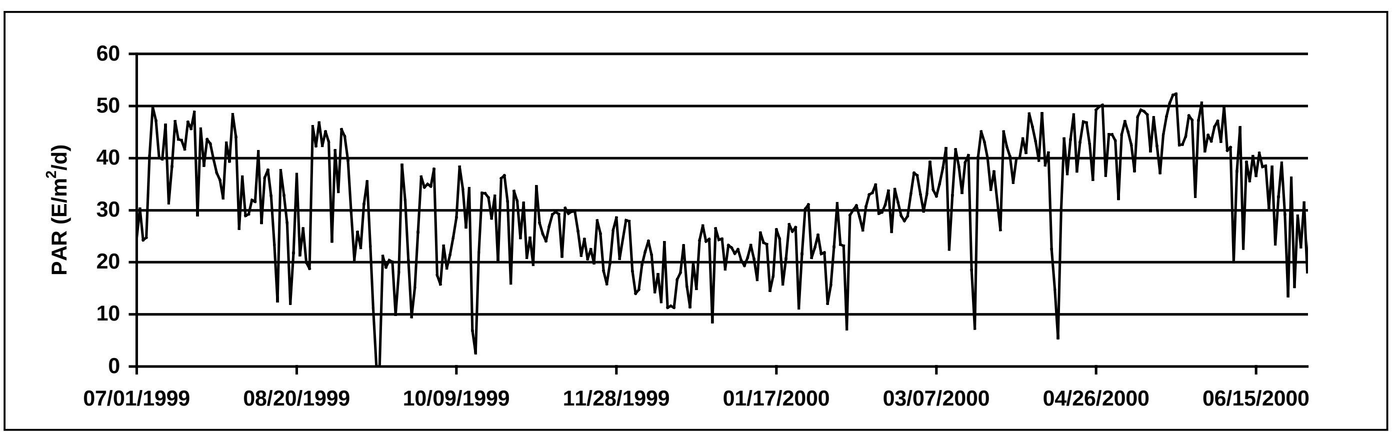


EXHIBIT 3-2
Photosynthetically Active Radiation Measured at the South ENR STRC



3.2 Air Temperature

On May 29, 1999, CH2M HILL initiated continuous monitoring of air temperature. An air temperature probe is mounted along with the solar radiation equipment at the South ENR STRC. Air temperature averaged 21.44, 24.69, and 25.85 degrees C during the April, May, and June study periods, respectively. Exhibit 3-3 presents average, maximum and minimum air temperatures recorded at the South ENR STRC.

3.3 Rainfall

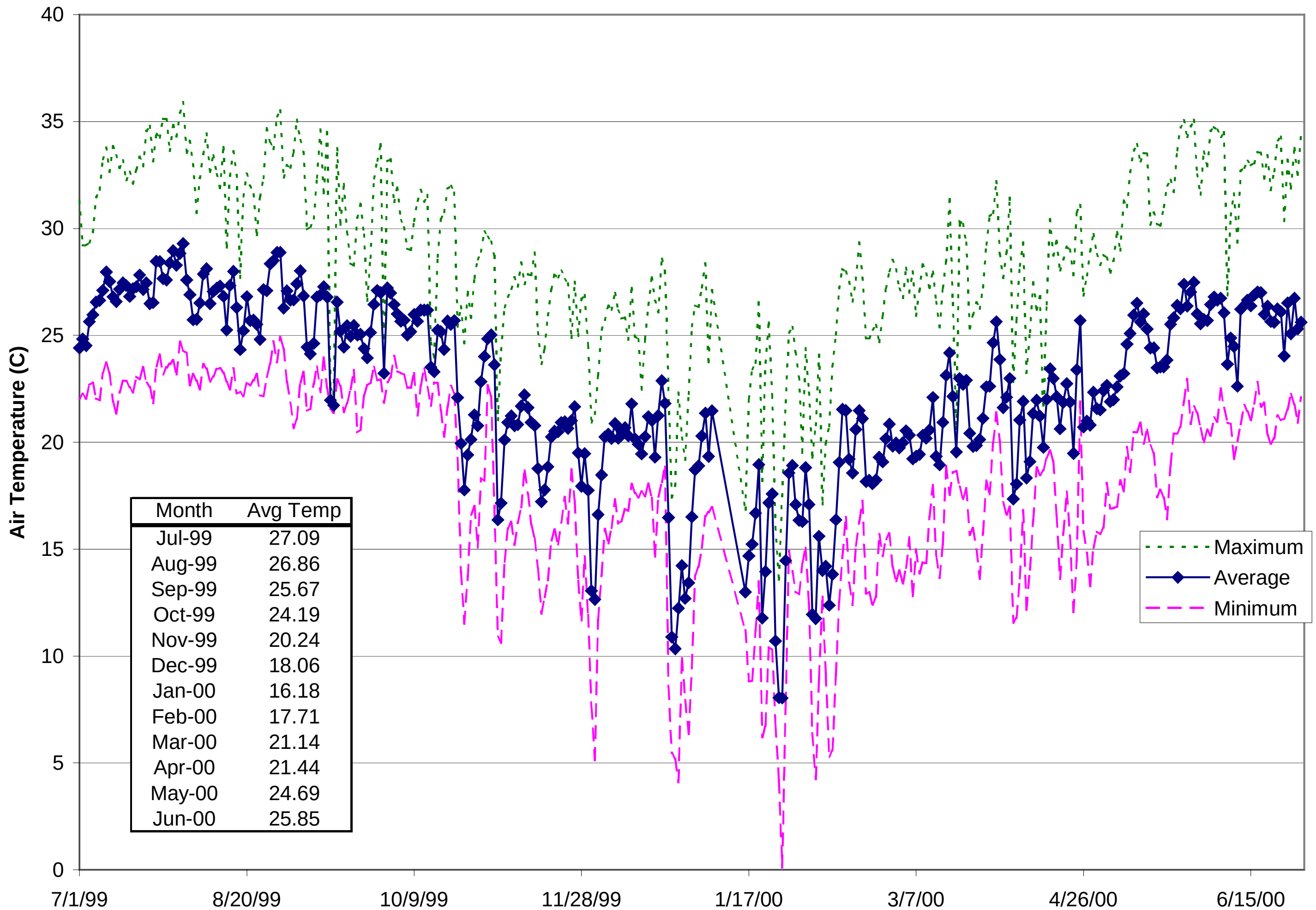
Daily rainfall data were provided by the District from ENR Rainfall Stations ENR301 (South) and ENR101 (North). Exhibit 3-4 illustrates daily total rainfall at each ENR Rainfall Station for the July 1999 through June 2000 study period. Rainfall during this quarter totaled 1.24 inches at the North Station and 7.03 inches at the South Station. Most of the quarterly difference in rainfall quantities between the two sites is attributable to April precipitation: there was approximately 4.2-inches more rainfall measured at the South site in April compared to the North site.

3.4 Evapotranspiration

Daily evapotranspiration (ET) data were provided by the District. Exhibit 3-5 illustrates daily total ET at the ENR Evapotranspiration Station ENRP for the July through December 1999 study period. No new ET data for this quarter were available from the District at the time of this report. For development of water budgets ET data from the same period for the previous year (April – June 1999) were substituted where necessary.

EXHIBIT 3-3

Average Daily Air Temperature Data at the South ENR STRC



4.0 MWTS Test Cells

4.1 MWTS North and South Test Cells

4.1.1 General Features

Exhibit 4-1 provides a general design summary of the MWTS Test Cells being monitored at the North and South MWTS Test Cells.

Exhibit 4-1
General Design Summary of the MWTS Test Cells

Site	Cell	Substrate	Target Water Depth (cm)	Target HLR (cm/d)	Treatment
North (NTC)	2	Peat	33	10.0	Ferric Chloride
	3	Peat	33	10.0	Control
	4	Peat	33	10.0	Aluminum Chloride
South (STC)	5	Peat	33	10.0	Control
	6	Peat	33	10.0	Control
	7	Peat	33	10.0	Aluminum Chloride

4.1.2 Operation of Chemical Treatment Units at ENR

Chemical treatment at the ENR site began on February 16, 2000 with the startup of the north aluminum pilot plant. Exhibit 4-2 summarizes the chronology of pilot plant operations. Target flow rate to the plant was started at 30 gallons per minute (gpm) for the first week, and was then increased to 37 gpm, which has been the target flow rate for all plants. The target flow of 37 gpm yields a hydraulic loading rate of 4 in/d (10 cm/d) to the wetland cells (incremental rate of 1 ft/d at the 1/3 sampling point in the cells).

A polyaluminum chloride product, HyperIon 1090, has been used since startup as the aluminum coagulant at the North Aluminum plant. The starting target dose was 1.5 meq/L. The initial polymer used was an anionic emulsion, Cytec N-1986, added at a dose of 0.5 mg/L.

EXHIBIT 4-2
Chronology of MWTS Pilot Plant Operations at the ENR

2/16/00	Started up north aluminum plant. Water flow was 30gpm. PACl dose was 1.5 equivalents. Cytec N-1986 emulsion polymer was dosed at 0.5 mg/L.
2/22/00	Started up iron plant.
2/29/00	Established target 37 gpm water flow at north plants
3/2/00	First wasted solids in iron plant
3/8/00	Began wasting 200 gallons/day in iron plant
3/17/00	Increased iron plant wasting to 300 gpd
3/17/00	Started up south aluminum plant.
4/17/00	First wasted solids in north aluminum plant
5/1/00	Began wasting 200gpd in north aluminum plant
5/3/00	Began 3-day on-site evaluation and jar testing. At the north aluminum plant, PACl dose was increased to 3 equivalents and polymer dose was increased to 1 mg/L. FeCl3 dose was increased 50% to 2.25 equivalents and polymer dose was increased 50% to .71 mg/L.
5/5/00	Switched to dry polymer, Cytec Superfloc A-130, at the north plants. Maintained new dosages.
5/6/00	South aluminum plant PACl dose was increased to 3 equivalents. Polymer dose was increased to 1 mg/L.
5/8/00	Switched to 1 mg/L dose dry polymer, Cytec Superfloc A-130, at the south aluminum plant . Began wasting 200gpd at same.
5/9/00	Increased iron plant wasting to 400 gpd.
6/10/00	Iron plant coagulant dose was increased to 3 meq/L. Aluminum plants' PACl dosage increased to 3.75 meq/L.

On February 22, 2000, the iron plant was started up at the North ENR site, using ferric chloride at a dose of 1.5 meq/L. Polymer type was Cytec N-1986 at a dose of 0.5 meq/L. Caustic is added to this plant to maintain pH in the coagulant addition zone of approximately 7 to 7.5 SU as previously determined from jar tests.

The aluminum plant at the south test cells was brought online the following month, with identical dosing used at the north beginning on March 17. For each plant, there was a two to three week debugging period during which target water and chemical flow rates were confirmed.

All three of the plants were operated with sludge recirculation from the plate settler to the flocculation zone.

4.1.2.1 North Test Pilot Evaluation

Following a roughly ten week operating period, a series of tests was conducted at the north pilot plants between May 3rd and 5th. The testing was conducted in response to laboratory results that indicated pilot plants were not yielding P removals expected based on jar tests. Thus, there was an interim conclusion that either the plants were not operating as expected, or that the water matrix had changed significantly from when the jar testing was conducted. The testing protocols were established by Luke Mulford and Paul Steinbrecher. Tests and evaluations were carried out under Dr. Mulford's direction. The main objectives of this focused testing were (1) to determine what process modifications could be implemented to reduce total dissolved phosphorus (TDP) concentrations in the plant effluents, and (2) to reduce solids carry over from the plate settlers.

Some adjustments to dosing have been required, due to higher TP concentration during startup as compared to waters used in jar tests used for setting dosages. Most operational changes were affected during the first week in May, when an intensive evaluation of operating conditions at the North site chemical units was conducted. (see North Test Pilot Unit Evaluation memo in Appendix D) The operational parameters that were evaluated and adjusted during the first week in May were as follows:

1. Chemical addition points were adjusted to maximize dispersion of the chemicals. The PACL addition point was moved from the first rapid mix chamber to the splitter box. The ferric chloride addition point was changed to disperse at approximately one inch from the impeller of the first rapid mix chamber, while the sodium hydroxide was injected into the raw water line up-stream of the chamber. The polymer addition point was moved to disperse at approximately one inch above the impeller of the second rapid mix chamber. While improvement to solids formation and settling was not evident, it is reasonable to believe that dispersion of chemicals was been enhanced.

2. Mixer/Flocculator Modifications. A larger impeller was evaluated in the polymer mixing chamber with the result of excessive vibration to the motor and excessive turbulence which effected the flocculation basin. The flocculation basin flocculator speed was reduced in the basins with marginal improvement on floc formation. The flocculator for the PACl pilot unit was reversed in rotational direction to mirror the direction of the ferric chloride unit. The rotation change was made to counter the direction of flow from the polymer chamber, thereby reducing the chance of short-circuiting. The combination mixing direction change and reduction of flocculator speed appeared to slightly improve floc formation.

3. Coagulant Dosage. The calibration procedure and feed rates of all chemicals were checked and verified as correct. Increasing the coagulant dose in combination with the polymer improved the floc characteristics slightly. On May 4, Fe coagulant dose was increased from the previous target rate of 28 mg/L as Fe to 42 mg/L as Fe. On May 6, aluminum coagulant dose was increased at both the north and south plants from the previous target of 13.5 mg/L to 27 mg/L as Al.

4. Polymer Type. Two additional polymers were evaluated by addition to the North pilot units. A high charge and high molecular emulsion (Cytec AF-126) was evaluated first on the PACl pilot unit. This product's effect was relatively fast and apparent with significant improvement in discrete floc formation and larger floc size. A significant

reduction in solids carry-over from the settler was not apparent. The high molecular weight, high charge, dry polymer used successfully by the CT/SS team (Cytec A-130) was applied to both North site pilot units. There was a significant enough improvement in floc particle formation that it was selected for a longer term evaluation at both sites and all pilot units. However, reductions of solids carry-over from the plate settlers were only marginal with the units in recirculation mode.

In summary the following steps were taken to address excessive floc overflow.

- Chemical addition points were adjusted to maximize chemical dispersion
- Floc formation was assessed and slightly improved by modifications to the mixing regime
- Hydraulic loading rate was verified by direct measurement of the plates
- Chemical dose rates and calibration procedures for measuring feed rates were checked and verified as correct
- Evaluations were made on various combinations of coagulant and polymer dose rates
- Two additional polymers were evaluated
- Settling characteristics were evaluated to determine if hindered settling was occurring

The excessive TDP concern was addressed by verifying sample collection procedures and testing possible pass-through by testing filtered and unfiltered fractions. In addition, possible feedback from the sludge storage tank was tested by comparing samples from the iron plant clarifier with the plant's effluent and coagulant samples were tested for contamination.

Conclusions drawn from the focused testing effort were:

1. At a coagulant dose of 1.5 meq/L (13.5 mg/L Al, 27.9 mg/L Fe) the TDP was not reduced below the 10 µg/L target immediately after the clarification process.
2. The TDP concentration of the solids storage tank effluent was not significantly different from the clarified samples indicating that feed back from the sludge was not occurring.
1. High solids did not appear to effect TDP after filtering (no discernable P bearing solids appear to pass the 0.45 µm filter.)
4. The dissolved residual metals concentration indicated that the coagulation process was relatively efficient.
5. The coagulants had measurable amounts of TDP ranging from 5 to 10 µg/L P at a dose of 1 meq/L (9 mg/L Al, 18.6 mg/L Fe)
6. Increasing the coagulant doses resulted in a measured TDP of 12 µg/L P. While this concentration was a historical low for the pilot units it was not clear that the increase in coagulant dose resulted in the reduction of TDP.

The following recommendation for future course of actions were made at that time:

- Consider reducing sludge age
  - To promote flocculent settling

- Extended sludge age did not appear to be providing excess P adsorptive capacity

- Continue to test the (dry) A130 polymer product which was effective for CT/SS.
- Verify that coagulants are free from contaminants
  - Submit serial dilutions
- Split samples among several laboratories to evaluate laboratory reliability

4.1.2.2 Changes Made After North Test Pilot Evaluation

On May 3, the PACl dose at the north aluminum plant was doubled to 3 meq/L and the $FeCl_3$ dose was increased by half to 2.25 meq/L, and polymer dose was doubled at the aluminum plant to 1 mg/L and increased roughly 50% at the iron plant to 0.7 mg/L. On May 5, we switched to the dry polymer product that was effective on the CT/SS project and continued dosing at the new rates.

On May 6, the same dose increase at the north aluminum plant was applied to the south plant. Two days later, on May 8, the switch to dry polymer was implemented at the south. One month later, on June 10, seeing little improvement in the TDP data, the iron coagulant dose was again increased to 3 meq/L. The aluminum plants' coagulant dose was increased to 3.75 meq/L.

4.2 Water Regime

The MWTS water regime includes the components of water depth, hydraulic loading rate, and water mass balance. Exhibit 4-3 summarizes the MWTS Test Cell water regime data for this quarter. Water level, inflow, outflow, and hydraulic loading rate (HLR) charts are presented in Appendix A.

4.2.1 Water Depth

Water level measurements in the MWTS Test Cells were recorded at the District staff gauge near the outflow of each Test Cell. Readings were taken weekly or more frequently. Daily average stage data were provided by the District for the North and South MWTS Test Cells. The target operating depth for the Test Cells is 0.33 m. For the fourth quarter the average cell depth was within 0.12 m of the target level in all cells.

4.2.2 Hydraulic Loading Rate

The HLR, q, is calculated using the following equation:

$$q\ (m/d) = Q/A \qquad \text{Equation 1}$$

Where:

Q = volumetric flow rate (m^3/d)
A = wetted area of the cell (m^2)

Daily average water inflows to the MWTS Test Cells are based upon the inlet splitter box at each site.

The target HLR for MWTS testing at the ENR is for the quarter was in the range of 8 to 10 cm/d. Actual average HLR in all cells in this quarter ranged from 6.83 to 7.56 (see Exhibit 4-3).

4.2.3 Water Balance

Exhibit 4-4 summarizes the water balance in each cell. The general balance between water storage, inflows, and outflows is shown in Equation 2:

$$\Delta V = V_{in} - V_{out} + P - ET - S \qquad \text{Equation 2}$$

Where:

ΔV = change in storage volume
V_{in} = inflow volume
V_{out} = outflow volume
P = precipitation
ET = evapotranspiration
S = seepage

Because the Test Cells are lined and seepage is assumed to be zero, the water balance equation can be re-arranged as shown in Equation 3:

$$V_{in} - V_{out} + P - ET - \Delta V = 0 \qquad \text{Equation 3}$$

At the conclusion of the baseline period (Q1 and Q2) a water balance for each test cell was developed (see 2nd Quarterly Report). In that analysis inflow and outflow balanced for only one of the six test cells, NTC 3. The high positive and negative residuals for the other five test cells indicated variation in one or more outflows and storage in response to a variety of factors. Over the course of the baseline period, water balance residuals were expected to become relatively small. The project team implemented a quality control plan for field data collection. Some of the steps include the following: 1) less frequent adjustment of weir height in water level 2) careful measurement of weir height setting, and 3) verify that our measurement of flow over the weirs is accurate. In addition we assessed the value of calculating the water balance on a daily basis rather than on a monthly average. The water balance calculations for Q1 and Q2 indicated that the magnitude of the residuals remain high.

Due to the uncertainty in estimating outflow from the weir setting Equation 3 has been utilized to calculate the outflow by difference (see last set of columns in Exhibit 4-4).

4.3 Field Parameters

Field parameters (water temperature, pH, dissolved oxygen [DO], percent saturation, total dissolved solids [TDS], and specific conductance) were measured in the MWTS Test Cells biweekly at the splitter box for raw water inflow, the point of discharge from the pilot plant into the marsh (Plant Effluent - PlntEff), two internal sampling points (1/3 and 2/3 monitoring walkways) and test cell outflow. Exhibit 4-5 depicts (in a simple schematic drawing) the sampling locations and water flow path.

Exhibit 4-4a

Exhibit 4-6 summarizes the monthly averages for field parameter data during this quarter and for previous quarters Averages were calculated from mid-depth measurements taken in the Head Cell and Test Cells. Additional graphical summaries of these parameters in Appendix B, temporal trend charts, and Appendix C, water quality gradients.

Temperature was relatively uniform across the head cell and Test Cells at the North and South (Exhibit 4-6) ENR sites. Other field parameters were affected by the chemical treatments. Relative to the raw water inflows pilot plant effluents had generally higher specific conductance, TSS and TDS values and lower D.O. Dissolved oxygen was, as anticipated, highly variable, since its values are influenced by microsite conditions (vegetation, water depth, cloud cover, etc.)

4.4 Water Quality Data

Two chemical treatment units at the north site (NTCs) (ferric chloride – NTC 2 and poly-aluminum chloride – NTC 4) and one treatment unit at the south site (poly-aluminum chloride, STC 7) operated for the entire quarter. The water quality sampling locations and sample site names are shown in Exhibit 4-5.

4.4.1 General Water Quality Results

At both north and south MWTS cells raw water inflows were sampled at the respective inflow splitter boxes mounted on one of the pilot plants at each site. Water coming from the Head Cell enters the splitter box, which is connected to pipes going to each of three wetland cells. The splitter box sends an equal amount of water to each of the cells to which it is connected. Water quality sampling for Q4 followed the routine schedule and protocols detailed in the MWTS research plan. STC 5, one of the two southern site control cells, was dropped from the general sampling regime at the end of Q4, since the statistical analysis of baseline period showed that STC 6 was the preferred control (see analysis in 2nd Quarterly Report). The information appropriate for STC-5 continues to be shown in the several tables and figures of this (Q4) report but STC 6 data will be used as the sole control cell for comparison with STC-7 starting in April 2000 (this reporting period).

The sample data thus collected were used to characterize inflow to all cells at each site, respectively. Samples were also collected from the effluent of each pilot plant (PlntEff), internal wetland sampling points, and the outflow of each test cell at varying frequencies. Phosphorus samples were collected at the highest frequency and were analyzed for a number of phosphorus forms. Test Cell raw water inflow, plant effluent (wetland inflow), internal sampling points (1/3 and 2/3 station) and wetland test cell outflow samples were collected biweekly for analysis of total phosphorus (TP), total dissolved phosphorus (TDP), and soluble reactive phosphorus (SRP). From the collected phosphorus data, total particulate phosphorus (TPP) was estimated by the difference: TP - TDP, and dissolved organic phosphorus (DOP) was estimated by the difference: TDP - SRP.

Test Cell inflows, plant effluent, internal 1/3 sampling stations and outflows were sampled monthly for total nitrogen (TN), total Kjeldahl N (TKN), total ammonia N (NH_3-N), nitrate nitrite N (NOx-N), calcium, total suspended solids (TSS), alkalinity, total organic carbon (TOC), total dissolved solids (TDS), color, chloride, sulfate, hardness, aluminum,

Exhibit 4-6a

Exhibit 4-6b

magnesium, iron, silica, and turbidity. From the collected nitrogen data, organic nitrogen was estimated by the difference: TKN - NH_3-N.

Monthly average values for water quality data collected from July 1999 through June 2000 are presented in Exhibit 4-7. Temporal trend charts comparing inflow versus outflow concentrations for TP, TPP, and TDP in each test cell are provided in Exhibits 4-8 through 4-13. Additional data summaries are provided in the appendices; included are inflow and outflow time series charts for parameters (Appendix B) and time series charts for water quality gradient within the wetland cells (Appendix C). Pre-July 1999 water quality data collected by the District in the north and south test cells have been added to the MWTS database. The District initiated sampling in September 1998 for NTC and November 1998 for the STC. The pre-MWTS data are included in the time series plots, Appendix B.

Several patterns of parameter behavior are evident from this quarter's and earlier data relative to a comparison of the inflow and outflow concentrations, assuming that under average conditions inflows roughly equal outflows. These general trends are provided by parameter for the North and South Test Cells in Exhibit 4-14, the summary includes results for Q1, Q2, Q3, Q4 and for the pre-MWTS monitoring (QO) where available.

Results, generally comparing constituent concentration of the raw inflow with test cell outflow, from the northern and southern ENR sites are as follows:

- Fe and Al treatments reduced TDP, SRP, TDP, DOP, TN, TKN, org-N, and TOC concentrations relative to the control. Color was reduced in both Al treatments.
- It appears that the wetland contributed TDP over the period of pilot plant operation (control cell results) but overall the treatment cells demonstrated net removal (NTC 2 and NTC 4), or little net change (STC 7).
- Due to episodic floc overflow TP and TPP concentrations in pilot plant effluent (inflow to wetland) were not consistently lower than the respective concentrations in the raw influent; however, TP and TPP concentrations in treatment wetland outflows were generally lower than the control cell outflows.
- TPP in the pilot unit effluent was quickly removed at the head of the wetland.

Exhibit 4-14
General Water Quality Trends for Inflow Versus Outflow Concentrations for North and South Test Cells

Parameter	General Trend for Inflow vs. Outflow Concentration					
	Inflow ≥ Outflow		Inflow = Outflow		Inflow ≤ Outflow	
	North	South	North	South	North	South
Phosphorus						
Total P	Q0, Q1, Q2, Q3, Q4	Q2		Q0, Q4		Q1, Q3
Total Particulate P	Q1, Q2, Q3, Q4	Q2				Q1, Q3, Q4
Total Dissolved P	Q1, Q2, Q3, Q4	Q3		Q4		Q1, Q2, Q4
Soluble Reactive P	Q1, Q2, Q3, Q4			Q1, Q2, Q3, Q4		
Dissolved Organic P	Q2, Q3, Q4		Q1	Q1, Q3, Q4		Q2, Q4
Nitrogen						
Total N	Q0, Q1, Q2, Q3, Q4	Q0, Q3		Q1, Q2		
TKN	Q0,Q1, Q2, Q3, Q4	Q4?		Q0, Q1, Q2, Q3		
Nitrate & Nitrate N	Q0	Q0, Q1, Q2, Q3,Q4	Q1, Q2, Q3, Q4			
Ammonia N	Q1, Q2, Q3, Q4	Q1, Q2, Q3, Q4				
Organic N	Q4		Q1, Q2, Q3	Q1, Q2, Q3, Q4		
Total Organic Carbon	Q4		Q0, Q1, Q2 Q3	Q0, Q1, Q2, Q3, Q4		
Total Dissolved Solids			Q1, Q2,Q3, Q4	Q0, Q1, Q2, Q3, Q4		
*Total Suspended Solids		Q0	Q0, Q1, Q2, Q3, Q4	Q1, Q2, Q3, Q4		
Color	Q4		Q1, Q2, Q3	Q1, Q2, Q3, Q4		
Chloride			Q0, Q1, Q2, Q3	Q0, Q1, Q2, Q3, Q4	Q3*, Q4	
Sulfate	Q1, Q4	Q1, Q2, Q4	Q2, Q3	Q0, Q3		
Alkalinity	Q0, Q3	Q0, Q3, Q4	Q1, Q2, Q4	Q1, Q2		
Hardness		Q0, Q1, Q3, Q4	Q1, Q2, Q4	Q2	Q3	
Aluminum	Q3	Q0, Q3*	Q4	Q1, Q2, Q4	Q1, Q2	
Magnesium			Q1, Q2, Q3, Q4	Q0, Q1, Q2, Q3, Q4		
Calcium		Q0, Q1, Q3, Q4	Q1, Q2, Q3, Q4	Q2		
Iron	Q1, Q2, Q3, Q4*	Q3		Q0, Q1, Q2, Q4	Q3*	
Silica	Q4	Q4*	Q1, Q2, Q3	Q1, Q2, Q3		
Turbidity			Q1, Q2, Q3, Q4	Q1, Q2, Q3		Q4

* Strongly cell dependent

4.4.2 Phosphorus

In the fourth quarter control cell NTC3 raw water inflow TP concentration was greater than that from the wetland outflow (Exhibits 4-7, 4-8, 4-9 and 4-10). This trend was often reversed for the control cells STC5 and STC6 (Exhibits 4-7, 4-11, 4-12, and 4-13). For both locations inflow TP was relatively evenly split between particulate and dissolved fractions.

Raw water influent [TP] was in a range of 115 to 230 ppb at the NTCs and 30 to 180 ppb at the STCs. This represents an increase over past quarters for both sites. NTC treatment wetland outflow (NTC 2 and NTC 4) TP concentrations were lower for the treatments compared to the control (NTC 3). Iron treatment (NTC 2) resulted in a 50-70% reduction and aluminum (NTC 4) a 50-85% reduction. The [TP] and [TPP] concentrations decrease from inflow to outflow. This result indicates that particulate P from the respective chemical treatment effluent was removed at the head of the wetland. The treatment effect on wetland outflow is evident in the time series plots (Appendix B)and gradient charts (Appendix C).

At the southern ENR location outflow [TP] was 10% to 20% lower for the aluminum treatment (STC 7) versus the control cell, STC6.

Phosphorus Species

Chemical analyses provide a breakdown of TP into total particulate P (TPP), total dissolved P (TDP), dissolved organic P (DOP) and soluble reactive P (SRP). A summary of each P-species is as follows:

- TPP—raw water influent TPP levels at NTCs were typically greater than or equal to levels at STCs (Exhibits 4-8 through 4-13 and time series charts in Appendix B). Water quality gradient data (Appendix C) show treatment effect on wetland outflow [TPP] for the fourth quarter. Outflow TP concentration was higher for the control (NTC3) relative to the chemical treatments (NTC2 and NTC4). As noted above, for the treatment period, [TPP] drop quickly in the wetland for both chemical treatment cells at the north site. For the quarter the northern treatment cells had inflow [TPP] in the range of 60 to 80 ppb. Monthly average outflow TPP concentration was 20 to 39 ppb for the iron treatment and the control, but was averaged 12 ppb for the aluminum treatment. For the STCs, inflow [TPP] averaged 30ppb. The outflow concentration for control cells were equal to or higher than the inflow; in contrast, the outflow concentration for the aluminum treatment averaged 20 ppb.

- TDP—NTC control cell (NTC 3) and treatments had lower outflow TDP concentrations as compared to inflow values. The average outflow [TDP] for the two treatments (Fe and Al) were, however, lower than the control, approximately 20 ppb as compared to 50 ppb. For the STCs the wetland influent [TDP] ranged from 20 to 80 ppb, and the wetland effluent ranged from 10 to 40 ppb. For the STCs there was no clear chemical treatment effect comparing inflow versus outflow [TDP] . The effect of treatment is apparent at the north site with significant reductions in [TDP] compared to the control (Exhibit 4-7, 4-8, 4-9, 4-10 and time series charts in Appendix B).

- SRP—Influent [SRP] rose steadily at the northern site for the quarter from approximately 18 ppb at the start to 115 ppb at the close. Influent [SRP] was higher at NTCs compared to STCs (averages of 45 ppb versus 11 ppb). At the southern site outflow [SRP] is typically less than 10 ppb for all three test cells. The aluminum treatments and the control at the north site were effective at reducing average SRP concentrations to less than 10 ppb.

4.4.3 Nitrogen

For the fourth quarter the raw water inflow [TN] was approximately equal at both sites (2.43 mg/l for NTC and 2.23 mg/L for STC) (Exhibit 4-7). Time series (Appendix B) display patterns of inflow [TN] that are remarkably similar among the three test cells at each location. At both locations the inflow and outflow TN values are approximately equal for the control cells (NTC3, STC6). NTC and STC results show a treatment effect with lower wetland effluent [TN] for the treatments as compared to the controls.

4.4.4 Other Water Quality Parameters

For several of the remaining parameters the inflow and outflow concentrations are approximately equal at the respective test cells (Exhibits 4-7 and 4-13). Included in this group are TDS, TSS, calcium, magnesium, and aluminum. Other observations for Q4 are as follows.

- Color—chemical treatments at both the northern and southern sites reduced color relative to the control. At the north site, the Al treatment resulted in lower color values than the Fe treatment. The control treatments at both sites had no apparent effect on color.
- TOC—results for the fourth quarter are similar to those for color, the chemical treatments at both locations resulted in lower outflow [TOC], compared to the controls. At the north site Al treatment resulted in lower TOC values relative to the iron treatment.
- Dissolved silica—results follow the pattern noted for color and TOC, reduced concentration for outflow as compared to inflow for Al and Fe treatments.
- The ferric chloride treatment (NTC 2) resulted in higher outflow concentrations of iron and chloride than the either the control or the aluminum treatment. At the remaining test cells the inflow and outflow values are approximately equal for iron and chloride.
- Hardness & alkalinity-for both parameters there are no apparent treatment effects at either the north or south site; outflow concentrations for controls and treatments are similar.

4.5 Mass Balances

Nutrient removal performance is most meaningfully quantified by a mass balance comparing the total loads entering and leaving the system. For example, phosphorus removal through physical, biological, and chemical processes, or export can be estimated simply as the difference between these loads. As an assessment of MWTS performance, inflow and outflow mass balances were estimated for each of the Test Cells. Mass balance estimates utilized the water balance calculated by the difference method using Equation 3.

Mass balance for P and N species were calculated on quarterly (Exhibit 4-15) and monthly intervals (Exhibit 4-16). These summaries were generated using weekly mass balance calculations, hence, only weeks when surface water samples were collected were included in calculating monthly averages. Contributions of rainfall to phosphorus and nitrogen loads to the Test Cells were not included in these mass loading estimates. Preliminary estimates indicate that rainfall load may make up between 1 to 10 percent of the total load. Final mass balance analyses for this project will include estimates of rainfall contribution to TP and TN.

Several patterns of parameter behavior are evident from the Q4 data regarding removal rates for phosphorus and nitrogen based on mass balances. The patterns are as follows:

- Inflow was greater than outflow—the wetland system was reducing or converting the influent load
- Inflow was approximately equal to outflow—the wetland system was having no significant effect on the influent load
- Inflow was less than outflow—the wetland was exporting of the constituent.

The mass balance trends are provided in Exhibits 4-17 through 4-21 for the phosphorus series and 4-22 through 4-26 for the nitrogen series. The plots show monthly and cumulative removals by constituent for all test cells.

4.5.1 Phosphorus

The net phosphorus removal (Exhibit 4-17) trend continued in Q4. Iron, control and aluminum treatments removed 67%, 50% and 79% of influent P load, respectively. At the northern site the monthly average removal rate increased over the quarter for both chemical treatments and the control (Exhibit 4-17). For the STCs where the trend for Q3 was net export of P, removal averaged 18% in the control cell and 20% in the Al treatment cell.

Phosphorus Species

A summary of each P-species is as follows:

- **TPP (Exhibit 4-18)**—patterns of removals for TPP are similar to those of TP at both locations. The NTCs show regular pattern of net removals on monthly and cumulative basis. The average TPP removal rate for the quarter was approximately equal for the control and iron treatments at 60%, while the aluminum treatment yielded a an average of 85%. The STCs exhibited month to month variation between positive and negative monthly TPP removal rates but the Al treatment cell had net removal for the quarter of 35% of the TP load due primarily to high loading and effective removal in April.
- **TDP (Exhibit 4-19)**—All NTC cells showed net TDP removal for the quarter, with the treatment cells much higher than the control cell percent removal. Net removal rates for the iron and aluminum treatment cells averaged 73% versus 42% for the control (Exhibit 4-15). The STC control and treatment cell removal rates were negative for April and May, positive for June, and positive overall. The control cell retained a higher fraction the TDP than did the treatment cell.
- **SRP (Exhibit 4-21)**—The northern test cells sowed net removal for SRP over the quarter with removal rates of 50%, 80%, and 90% for iron, control, and aluminum

treatments, respectively. For the STCs both the control (STC6) and aluminum treatments had removal rates in range of 50% to 60%.

- **DOP (Exhibit 4-20)**—DOP removal rates are variable at all locations except for the NTC Al treatment (NTC-4), which displayed a consistent removal of DOP. Overall quarterly mass balance (% removal) was similar for the NTC iron and Al treatments.

4.5.2 Nitrogen

A treatment effect is apparent at the NTCs for the fourth quarter (Exhibits 4-16 and 4-22). TN removal averaged 40% for the iron treatment, 47% for the aluminum treatment, and 17% for the control cell. At the south site, the quarterly mean percent mass removal rates were both positive and very similar in magnitude to their counterparts in the NTC.

Nitrogen Species

A summary of each N-species (TKN, TNOx, NH4-N, and Org-N) is as follows:

- **TKN (Exhibit 4-23)**— pattern and magnitude of removals for TKN closely duplicate those for TN for both the treatment and pretreatment periods in the quarter.

- **TNOx (Exhibit 4-24)**—inflow and outflow [TNOx] are typically very low at the north site, therefore slight differences in the inflow versus outflow concentration result in fluctuation between positive and negative removals. At the south site there has typically been a net TNOx removal on a monthly and cumulative basis.

- **NH4-N (Exhibit 4-26)**—for Q4 there was a high (87% – 89%)net removal of ammonia-N in all NTC treatment cells. Removal of NH4-N in the STC control (55%)and treatment cell (76%) was similar to previous quarters' performance.

- **TON (Exhibit 4-25)—**the quarterly TON removals were positive for all cells. Control cells averaged 7% and 16 % removal (north and south respectively). Al treatments in north and south sites removed similar fractions of the TON load (46 and 45%) while the Fe treatment removed a net 33%.

5.0 Treatment Pond Design

The Cypress demonstration area is located on the Seminole Indian Reserve. The project has been separated into two parts. Part 1 includes construction of system components and several months of hydration and conditioning of the 4-acre wetlands demonstration area. The construction activities were completed during the quarter. This includes construction of the raw water pump and associated electrical work, transmission piping to the wetlands demonstration area, and a splash pad at the discharge point. Wetland hydration began in after the close of Q4, late July 2000. Part 2 includes construction of a chemical treatment system and a treatment pond. Both systems will connect to the Part 1 transmission pipe. Phase 2 tender is expected by the end of October 2000, pending permit approval for discharge of treated water to wetland.

5.1 Description of the Cypress Demonstration Pilot

5.1.1 Objectives

The goal of this project is to reduce phosphorus concentration in wetlands water to acceptable levels while minimizing mechanical requirements. Phosphorus reduction will occur in two stages, chemical precipitation (chemical treatment/treatment pond) followed by natural chemical stabilization in the ecosystem (wetlands). A process schematic is shown in the attached Exhibit 5-1.

5.1.2 Water Supply and Transmission

After the raw water supply and transmission system has been installed raw water will be pumped from the West Feeder canal at 100 gpm directly to the wetlands test area to hydrate and condition the test area. During this conditioning period, the raw water supply and delivery system will be capable of supplying an additional 50 gpm of raw water to the chemical treatment/treatment pond system for preliminary testing. After the hydration period, raw water flow will be diverted at 100 gpm to the chemical treatment/treatment pond system which will discharge to the wetlands test area.

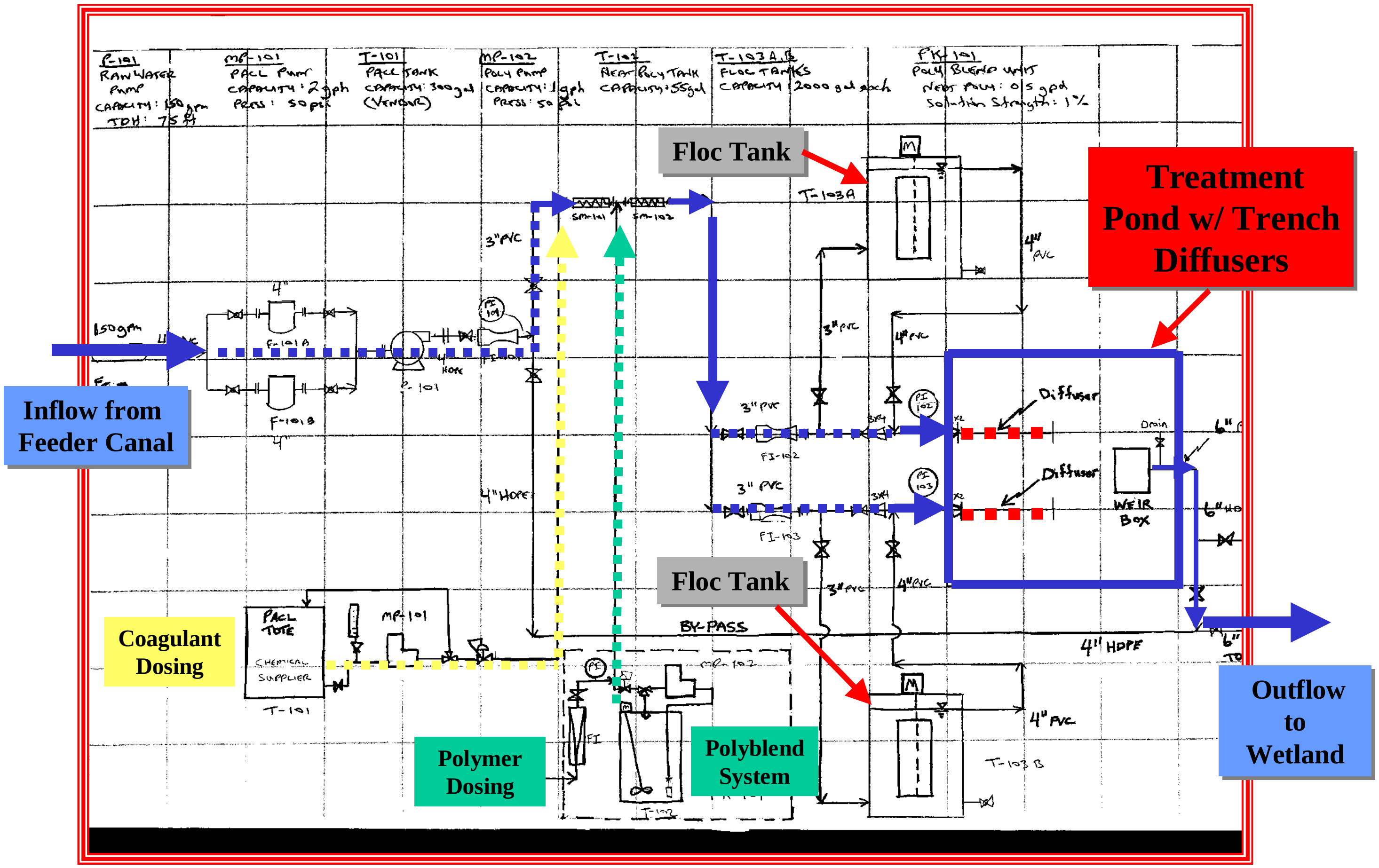
5.1.3 Chemical Treatment

Chemical treatment is intended as the primary method of phosphorus removal. The purpose of adding aluminum or iron salts to the process is to precipitate and adsorb phosphorus. It is anticipated that the primary chemical to be used for phosphorus removal will be polyaluminum chloride (PACL). An anionic polymer will also be added to increase particulate removal efficiency in the pond.

For chemical addition, electronic diaphragm metering (pulse) pumps will be used. Chemical flow rate will be adjusted manually at the pulse pumps by varying the pulse rate and/or the stroke length. PACL will be fed as neat chemical from the chemical supplier to tote tanks. Extra tote tanks will be stored on the pad to provide a minimum of 30 days storage.

Exhibit 5-1
Process schematic pond treatment system.

Process Schematic Pond treatment system



Polymer will be made up as a 1% solution using a packaged liquid polymer blending and feed system mounted on a 55 gal polymer drum. Polymer dilution water is available at the site.

All chemical treatment equipment will be placed on a poured concrete pad adjacent to the pond as shown in Exhibit 5-2 (Plan And Profile – Pond and Trench Treatment System). The pad will include space for in-line static mixers, chemical pumps, chemical solution tanks, flow indicators, control valves, chemical storage, and flocculation tanks. The chemical pump and chemical storage area will include a containment curb to contain chemical spills. PACL will be supplied in 300 gallon tote tanks by the chemical supplier. Concentrated liquid polymer will be supplied in 55 gallon drums. An access ramp will be provided for chemical delivery. All electrical equipment on the chemical treatment pad will be 120 V single phase and will have plug-in connections to eliminate hard wiring requirements. A partial rain shelter will cover the electrical equipment.

The chemical treatment system includes two 2000 gallon flocculation tanks with picket-fence type adjustable speed mixers. The flocculation tanks will be downstream of chemical injection and will provide 30 minutes of flocculation time. If required, chemically treated water will be diverted to the flocculation tanks to provide additional flocculation time prior to entering the treatment pond.

5.1.4 Treatment Pond

The treatment pond (pond) shown in Exhibit 5-3 (Cross Sectional Profile of Pond Treatment) will be used for solids contact, solids separation, and residual solids storage. The pond area will initially be leveled at an elevation of 9 ft. A 4-foot high berm will be built around the pond and the normal water level will be at 3.5 ft from base. The pond will be lined with 40-mil high density polyethylene (HDPE) geomembrane and has enough solids storage volume for approximately 3 months of operation at which point solids will be removed and trucked for disposal.

Chemically treated water will flow through 2 distribution pipes running along the base of the pond. Each distribution pipe is located in a two-foot deep trench sized to hold about 3 days of precipitated solids. The distribution pipes are equally spaced and have hole patterns to provide uniform water distribution. Once the pipe trenches fill with solids, solids contact will occur with the inlet water. Solids removal occurs as water flows upward through the sludge blanket. A weir box at the far end of the pond will be used to set the water level in the pond and to collect treated water. By using a thicker rubber sheet or two 40-mil HDPE sheets, the concrete slab for the weir box can be placed directly on the geomembrane. The weir box will be blocked at the front and back and will have adjustable weirs on the sides. Treated water will flow over the weirs and out through the discharge pipe at the base of the weir box.

5.1.5 Wetlands Treatment

Treated water flows by gravity from the pond weir box through the discharge pipe to the wetlands application location. The pipe will discharge at a single point. As the water discharges, it will spread out over the wetlands treatment area. A uniform water level in the wetland will be maintained by using an inflatable dike at the far end of the wetlands treatment area.

Exhibit 5-2
Plan and Profile – Pond & Trench Treatment System

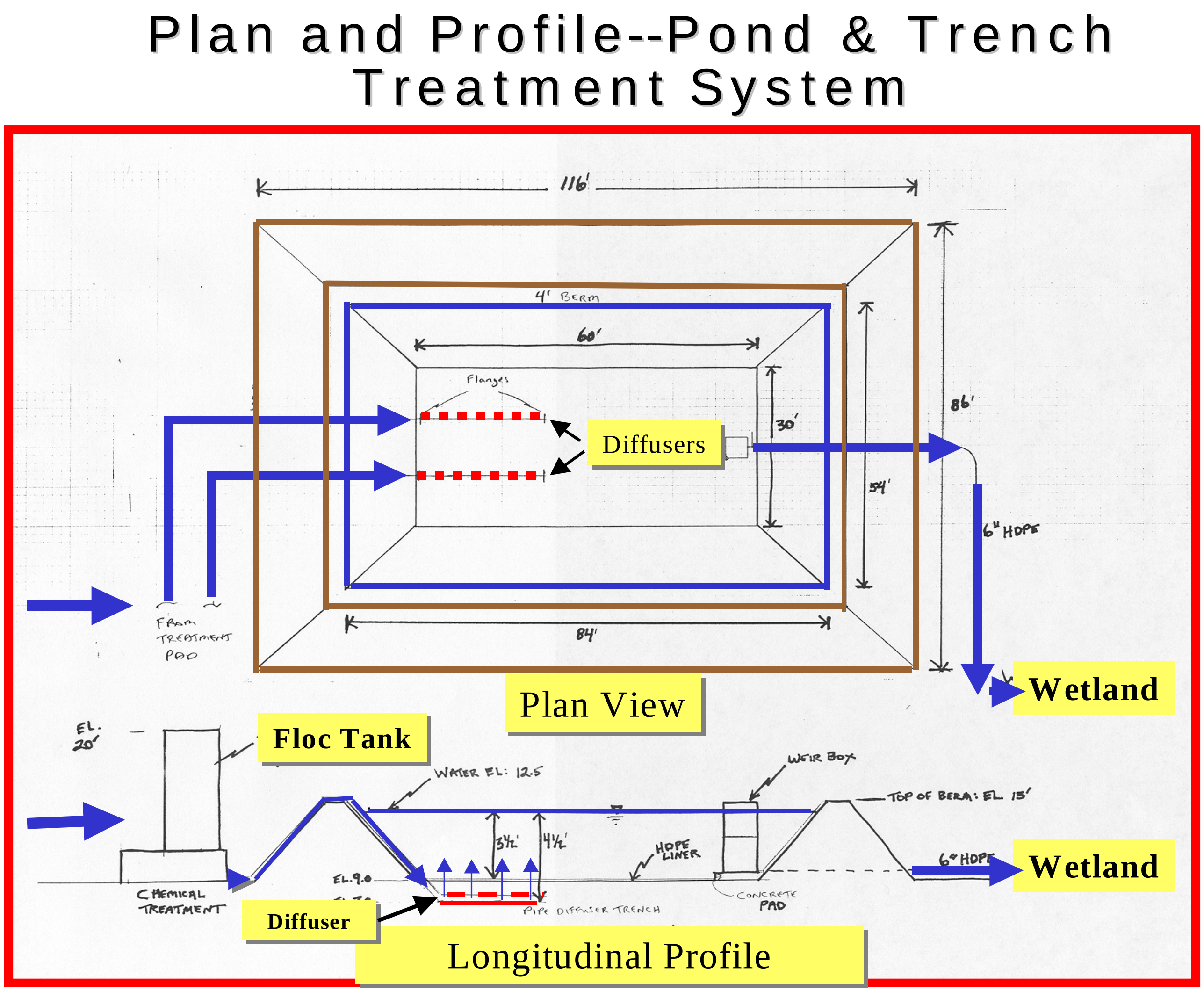
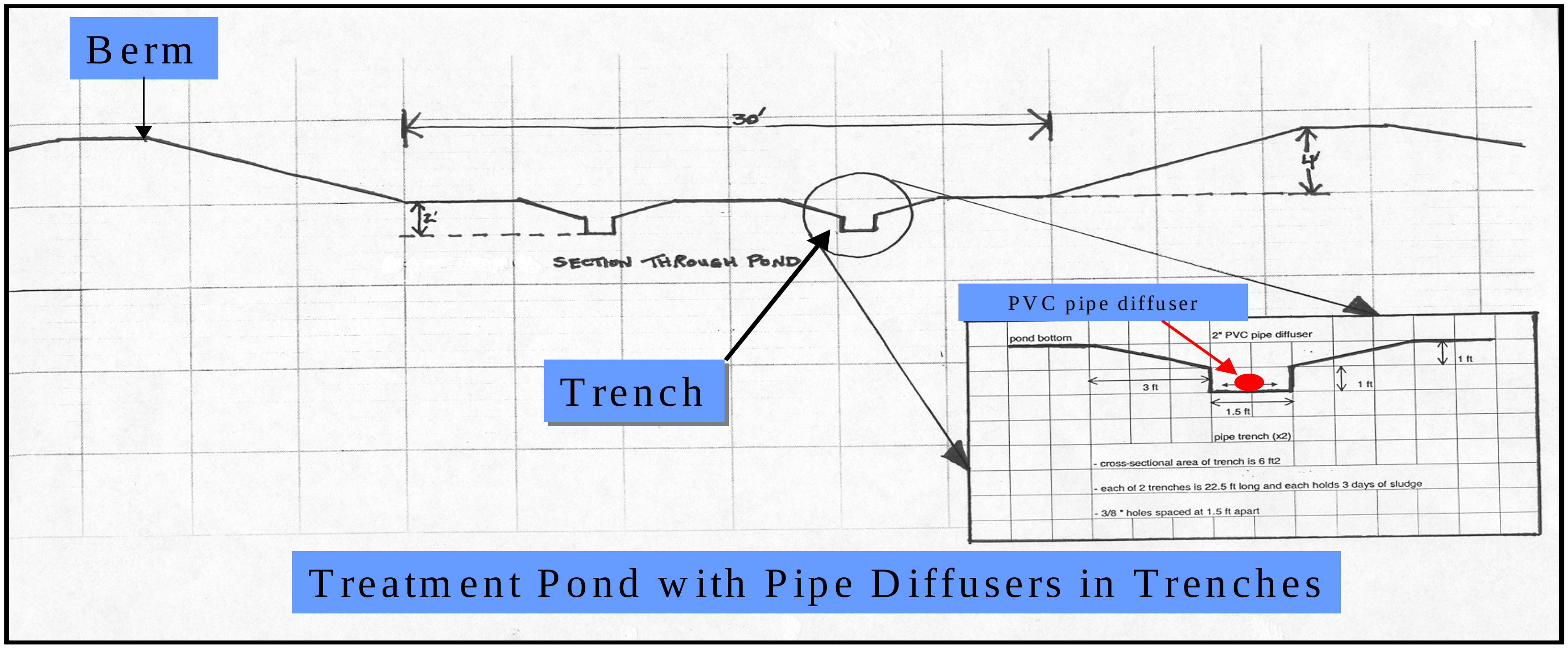


Exhibit 5-3
Cross Sectional Profile of Pond Treatment System

Cross Sectional Profile of Pond Treatment System



6.0 Marsh Readiness and Ionic Conditioning

One of the defining aspects of MWTS is the role of the wetland system in ameliorating the changes to the chemical signature of the water effected by chemical treatment. The concern is whether chemically treated waters are "marsh ready," that is, of acceptable quality to be discharged to the marshes of the Everglades ecosystem.

To date, the measures by which marsh readiness will be assessed have not been defined. There are several existing graphical methods for characterizing the chemistry of waters. Several of these approaches focus on ionic constituents, specifically anions and cations. The approaches include comparisons by stacked bar charts for anions and cations, pattern diagrams (Stiff diagrams) developed for oilfield drilling, log diagrams (Schoeller plots), radial charts, and trilinear plots.

For an initial comparison, modified Stiff diagrams were selected. Stiff diagrams have been used extensively by the USGS, and they have recently been used for comparing the quality of ground and surface waters at the Phase 2 field site for the periphyton storm water treatment (PSTA) project.

The parameters used in the Stiff diagrams are chloride, sulfate, bicarbonate, calcium, magnesium, and iron . The diagrams were developed by converting each ionic constituent concentration to a millequivalent value. Positively charged constituents were plotted on the left side of the diagram opposite negatively charged constituents on the right. Waters with comparable water quality will form similar shapes from connecting the resulting points (Todd, 1959). Masses, absolute values of the ion charge assumed for the constituents, and conversion factors are shown in Exhibit 6-1.

Exhibit 6-1.
Calculation data for conversion of concentration data (mg/l) to milliequivalents per liter (meq/l).

Constituent	Atomic Weight	Ion Charge	Conversion factor (divisor)
Chloride	35.453	1	35.453
SO4	96.056	2	48.028
HCO_3^-	61.016	1	61.016
Aluminum (ug/l)	26.982	1	26.982
Magnesium	24.305	2	12.153
Calcium	40.080	2	20.040
Iron	55.847	3	18.616

Schoeller plots were also chosen to characterize the water chemistry in the MWTS. Ion concentrations, in milliequivalents per liter, are plotted on a logarithmic scale. The points generated are then joined by straight lines. If the line connecting two points in one sample is parallel to the same line from a different sample, then the ratio of ions in both water samples is equal (Todd, 1959).

Another method chosen to represent the water chemistry data is Radial plots. Ion concentrations, expressed in milliequivalents per liter, are plotted in counter-clockwise order. Radial plots are somewhat similar to Stiff diagrams in that the radially plotted points are connected to create a shape that can be used for comparing ionic concentrations of different water samples.

All three of these graphical methods are used to display and compare water quality results. Both the Stiff and the Radial plots create shapes that can be used to compare water quality between different samples. However, it is easier to detect when a water quality parameter deviates from other samples using the Schoeller plots. This is because Schoeller plots show both the absolute value of each chemical parameter and the concentration differences between samples (Todd, 1959).

Using each of the three methods described above, the chemical composition of all the MWTS NTC and STC were plotted for the calibration period of August 1999 through January 2000 (Exhibit 6-2) (Exhibit 6-3) (Exhibit 6-4). Also using the methods described above, chemical composition for the MWTS NTC and STC for the period of March 2000 through June 2000 (treatment) were plotted (Exhibit 6-5) (Exhibit 6-6) (Exhibit 6-7). For comparison, the Loxahatchee National Wildlife refuge (WCA 1) (1996-1998), Water Conservation Area 2A (WCA-2A) (1996-1998), and Conservation area 3A (WCA-3A) (1977-1983)(SFWMD 2000, Swift and Nichols 1987) were plotted using the same methods(Exhibit 6-8) (Exhibit 6-9) (Exhibit 6-10). It should be noted that all of the ions in all of the diagrams are expressed in milliequivalents per liter, except for iron, which is expressed as microequivalents per liter.

Diagrams of average values of ionic constituents for the six treatment wetlands for the pretreatment period August 1999 through January 2000 (Exhibits 6-2, 6-3, 6-4) are very similar. The north site cells (NTCs) appear to have a slightly higher iron component values but the overall patterns are quite similar. Comparison of the calibration period diagrams with treatment period diagrams shows that treatment had little effect on ionic conditioning. The iron cell (NTC –2) has an increased iron component, skewing the diagram for that cell somewhat. The aluminum cell (STC-7) had a slight reduction in calcium. Otherwise, ionic conditioning of the two treatment cells was very similar to that of the control cell.

A comparison of the test cell data with data from the Water Conservation Areas is a useful method of extending the comparison to consider the question of overall “marsh readiness” of the water. Comparison of the treatment period data with WCA data suggests that the test cell effluent ionic condition is very similar to that found in the interior of WCA 2. The exception is NTC-2, the iron treatment.

Exhibit 6-2. Stiff diagrams of test cell chemical composition. Values are averages of data from August 1999 through January 2000 converted to milliequivalents per liter (meq/l)

Exhibit 6-3. Stiff diagrams of average values for ionic components of NTC cells for March 2000 converted to milliequivalents per liter (meq/l).

Exhibit 6-4. Stiff diagrams of ionic species in samples from interior sites in the Loxahatchee National Wildlife refuge (WCA 1), Water Conservation Area 2A (WCA-2A), and Conservation area 3A (WCA-3A) (SFWMD 2000, Swift and Nichols 1987). Original values were converted from mg/l to milliequivalents per liter (meq/l).

7.0 References

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APPENDIX A

Water Regime Time Series Charts

Note:

- North Test Cells
  - Test Cell 2 = NTC 2 iron (Fe) treatment cell
  - Test Cell 3 = NTC 3 control cell
  - Test Cell 4 = NTC 4 aluminum (Al) treatment
- South Test Cells
  - Test Cell 5 = STC 5 control cell
  - Test Cell 6 = STC 6 control cell
  - Test Cell 7 = STC 7 aluminum (Fe) treatment cell

APPENDIX B

Water Quality Time Series Charts

Note:

- North Test Cells
  - NTC 2		iron (Fe) treatment cell
  - NTC 3		control cell
  - NTC 4		aluminum (Al) treatment
- South Test Cells
  - STC 5		control cell
  - STC 6		control cell
  - STC 7		aluminum (Fe) treatment cell

APPENDIX C

Quarterly Boxplot Charts

Note:

- North Test Cells
  - Cell 2 = NTC 2 iron (Fe) treatment cell
  - Cell 3 = NTC 3 control cell
  - Cell 4 = NTC 4 aluminum (Al) treatment
- South Test Cells
  - Cell 5 = STC 5 control cell
  - Cell 6 = STC 6 control cell
  - Cell 7 = STC 7 aluminum (Fe) treatment cell

APPENDIX C

Water Quality Gradient Time Series Charts

Note:

- North Test Cells
  - NTC 2 iron (Fe) treatment cell
  - NTC 3 control cell
  - NTC 4 aluminum (Al) treatment
- South Test Cells
  - STC 5 control cell
  - STC 6 control cell
  - STC 7 aluminum (Fe) treatment cell

APPENDIX D

Memorandum – North Test Pilot Unit Evaluation